INVENTING THE FUTURE: ENERGY AND THE CO_2 "GREENHOUSE" EFFECT

E. E. David Jr.

President, Exxon Research and Engineering Company
Remarks at the Fourth Annual Ewing Symposium, Tenafly, NJ

Dennis Gabor, A winner of the Nobel Prize for Physics, once remarked that man cannot predict the future, but he can invent it. The point is that while we do not know with certainty how things will turn out, our own actions can play a powerful role in shaping the future. Naturally, Gabor had in mind the power of science and technology, and the model includes that of correction or feedback.

It is an important: Man does not have the gift of prophecy. Any manager or government planner would err seriously by masterminding a plan based unalterably on some vision of the future, without provision for mid-course correction. It is also a comforting thought. With man's notorious inability to create reliable predictions about such matters as elections, stock markets, energy supply and demand, and, of course, the weather, it is a great consolation to feel that we can still retain some control of the future.

As you may know, Exxon is a hundred years old this year; we have a long corporate memory of the very profound social and economic transformations that our business activities have helped bring about, and of how we and society have had to adapt further in response. That includes the at least temporary respite given to the whales through substituting kerosene lighting fuel for their rendered blubber; as well as the revolutionary changes wrought by the automobile and other machinery powered by liquid hydrocarbon fuels. The primary factors guiding such developments were technology and economic markets, though political systems also played their role.

But faith in technologies, markets, and correcting feedback mechanisms is less than satisfying for a situation such as the one you are studying at this year's Ewing Symposium. The critical problem is that the environmental impacts of the CO_2 buildup may be so long delayed. A look at the theory of feedback systems shows that where there is such a long delay the system breaks down unless there is anticipation built into the loop. The question then becomes how to anticipate the future sufficiently far in advance to prepare for it.

One answer is to invent the future in another way--through a system of contingency planning based on an assessment of a number of futures. As Harvey Brooks has noted, scenarios have limited use if they are merely surprise free projections of current trends; instead, they must somehow take into account those clouds on the horizon no bigger than a man's hand that can turn out to be dominant influences in twenty years. Inadequate scenario-making explains the poor performance of most social research to date--which so often gives the sense of too little too late, whether the topic is toxic waste, frost belt and sun belt, or the shift from manufacturing to information society. The key is to undertake research that will tend to be independent of future events, or, rather, relevant across a broad spectrum of scenarios.

This is not easy to do, but some of Exxon's own research and development strategy is aimed in that direction. And Exxon is not the only company with this attitude. That is why we and others in the petroleum industry have taken a strong interest in the issue of the greenhouse effect and your work. It is why we have participated in several initiatives to promote your research; it is why we are pleased to contribute to the holding of this symposium and to participate in it. And it is why we have begun our own modest research effort in the field, motivated also by the belief that perhaps the only way to understand a field is to do research in it. You have seen some of the results in a paper delivered yesterday afternoon. We are also in the process of evaluating the data on CO_2 concentrations collected over two years by an Exxon tanker plying between the Gulf of Mexico and the Gulf of Arabia.

Organization

Few people doubt that the world has entered an energy transition away from dependence upon fossil fuels and toward some mix of renewable resources that will not pose problems of CO_2 accumulation. The question is how do we get from here to there while preserving the health of our political, economic and environmental support systems. What I will do in the remainder of this talk is indicate how the world may invent a successful energy future, using the sort of corrective feedback system I have described. My perspective is of course an Exxon perspective, reflecting our own assumptions about the economic and social paths societies will prefer. And since fossil fuels, and liquid chemical fuels, are really the heart of the energy and the CO_2 problem, I will focus on those.

My plan of attack is, first, to consider the implications of recent energy developments. Then I will describe some of the key assumptions that are guiding Exxon's own R&D planning and which, I think, we have in common with many other actors in the scene. Finally, I will go on to mention some of the technical possibilities that may present themselves well beyond our usual twenty-year outlook period, that is, fifty years or more into the future.

While I am far from certain about the details, I think you'll find that I'm generally upbeat about the chances of coming through this most adventurous of all human experiments with the ecosystem.

Recent Energy History

It is ironic that the biggest uncertainties about the CO_2 buildup are not in predicting what the climate will do, but in predicting what people will do. The scientific community is apparently reaching some consensus about the general mechanisms of the greenhouse effect. It is considerably less agreed on how much fossil fuels mankind will burn; how fast economies will grow; what energy technologies societies will foster and when; and so how fast the buildup will occur.

But we do know about the recent past and the present. In the aftermath of the energy price increase of the past decade, consumers have reacted to the price feedback mechanism very much as classic economic theory would predict. They have sharply reduced their energy consumption and, in particular, their consumption of oil. They have substituted other fuels like coal and nuclear for petroleum, although more coal use does <u>increase</u> CO_2 emissions. Consumers have also conserved by turning to more energy efficient technologies, including smaller cars in the U.S. And they have done without.

It is difficult to disentangle the effects of conservation from the effects of recession. According to a recent report from the International Energy Agency, they are about equal. We think conservation effects are larger, but regardless, energy consumers have certainly broken the lockstep relationship between economic activity and energy consumption that seemed to prevail for a quarter century following World War II. For example, according to the International Energy Agency, it now takes 16 percent less energy and 26 percent less oil to produce 1 percent more of output in the non-communist industrialized countries than in 1973.

This development carries great significance for the CO_2 buildup. Consumers and technologists have been inventing and applying a wealth of methods to extract more work from less energy. For example, as one of our own biggest energy customers, we at Exxon have stepped up the efficiency of our refineries by twenty percent since 1973. Because refining is so energy-intensive, the energy savings, and the corresponding reductions of CO_2 emissions, have been very large indeed. Last year the savings amounted to the equivalent of some 28 million barrels of oil--equal to the production from a world-scale, 50,000-barrel-per-day synthetic fuels plant. On top of that, we have set the goal of doubling our refining efficiency by the year 2000, and we think the goal is realistic.

How far will the conservation trend go? It is too early to say for sure, but we think the implications apply very far into the future. And how far will the energy mix tend to favor fuels, such as coal, that produce large amounts of CO_2, rather than fuels with high ratios of hydrogen to carbon, such as gasoline and methane? To some extent the answer to that question depends upon our ability to come up with a source of low cost hydrogen based on non-fossil energy--a point I'll return to later.

Fossil Fuel Outlook: Key Assumptions

In assessing alternative futures, I would offer three assumptions in the form of predictions about the use of energy and fossil fuels.

First, nearly all societies will continue to give primacy to economic growth. The human desire to improve material conditions burns as bright as ever, if not brighter. As we have seen most recently in Poland, governments that fail to deliver at least a convincing promise of growth suffer dire consequences as a rule. With the overall world population expected to double over the next 50 years, economies and energy use will have to grow at a good clip just to hold per capita incomes even. Naturally, the pressures for growth will be greatest in the developing world, where populations are growing fastest.

A second assumption, one that follows from the first, is that in pursuit of growth most societies will prefer least-cost energy alternatives. I say this with the recognition that at least a few developing countries will prefer options that utilize local resources in order to conserve foreign exchange or use local labor, no matter what the cost. An example is Brazil's resort to alcohol fuels extracted from its sugar cane. However, such exceptions will not materially alter the world future.

The third assumption is that societies will continue to prefer the efficiencies of fossil-based liquid fuels in transportation uses. Because conventional petroleum resources will not suffice to meet the demand, a major industry will begin to grow around the turn of the century to produce synthetic fuels from oil sands, oil shale, and coal.

Despite the trend toward electricity, the electric vehicle will have trouble making significant inroads in transportation markets over the next twenty years. One problem is storage, which is partly a problem of energy density. Today's lead-acid batteries store about 1/300th the energy of a like weight of gasoline. We can improve on that; in fact, Exxon is in the middle of developing a zinc-bromine battery with two to three times the capacity of conventional lead-acid batteries. Another problem is the cost of batteries. They are expensive, mainly because of the cost of raw materials and typically short life cycles. Incidentally, we expect that load leveling, rather than the electric car, will be one of the earliest applications of our new battery. However, we would certainly not rule out the electric car one day--perhaps initially in the form of hybrid vehicles powered by batteries in tandem with small gasoline or diesel engines.

Another alternative features electric guideway systems in which vehicles use batteries on the feeder roads and electrically induced power along the main arteries. But the capital costs of such a system would be immense--making it a viable option only for much richer societies than we can foresee.

Granted, liquid fuels-like all chemical fuels-have their share of problems. In burning they may synthesize some unfriendly substances--such as PNA's, NO_x, SO_x and CO_2. Still, there are also well-known problems with producing electricity through non-chemical means, such as nuclear power. Solar voltaics overcome many of these drawbacks, but the inherent problems of the duty cycle and storage make me skeptical that solar voltaics will penetrate a large fraction of the electricity market in the near future, except in remote applications.

But to reiterate my main theme, such assumptions only act as a guide in determining where R&D managers can most usefully concentrate resources for inventing the future, subject to correction and further feedback. In any case we are not up against fatal, malthusian limits to growth. On the distant horizon, we may discern a peaking of petroleum production; because for more than a decade the world has been consuming pertroleum faster than the industry has been replacing it. But remaining non-petroleum fossil fuel resources are immense. As an example, in 1980 oil and gas production accounted for nearly 70 percent of the world's production of fossil energy. But oil and gas reserves account for only a little over 11 percent of the world's estimated total recoverable fossil energy resources.

As a practical matter, you would surely agree that the world economy is committed to using fossil resources for some time to come. The massiveness of the energy system in place simply forbids immediate displacement of one fuel or energy source by another. Historical market studies going back to wood and coal confirm this idea, suggesting that a new energy source requires about 50 years to achieve just half the total energy market.

What are Exxon's projections for fossil fuel use? Over the twenty years encompassed by our normal outlook we estimate the fossil fuel use will grow at the equivalent of about two percent per year. Much of this growth will occur in the developing countries, as they modernize their economies.

Beyond our normal twenty-year outlook period, we recently attempted a forecast of the CO_2 build-up. We assumed different growth rates at different times, but with an average growth rate in fossil fuel use of about one percent a year starting today, our estimate is that the doubling of atmospheric CO_2 levels might occur sometime late in the 21th century. That includes the impacts of synfuels industry. Assuming the greenhouse effect occurs, rising CO_2 concentrations might begin to induce climatic changes around the middle of the 21th century.

Manufacturing synthetic fuels will produce more CO_2 than conventional petroleum fuels, but the impact of substituting synthetics for depleting petroleum supplies will be relatively small. If, in our estimate, we back out synfuels and replace them with conventional petroleum fuels, the difference in CO_2 emissions would only add about five years to the doubling time. This is a highly conservative estimate, because it assumes that industry in the 21st century will continue using today's "Dinosaur" technologies for manufacturing synfuels, with no increase in the efficiency of these highly energy-intensive processes. And it takes no notice of the trends we are already seeing today in this budding information age. As John Pierce, the inventor of satellite communcations, likes to say, soon we may be traveling for pleasure but communicating to work. Such developments could eventually go very far in reducing the energy intensity and CO_2 emissions of advanced economies.

Exxon's Response in Science and Technology

The real point of these extrapolations is to get an understanding of how soon the problem may become serious enough to require action. And the lesson is that, while the issue is clearly important, we can still afford further research on the problem. And the world will have time to accumulate the material and scientific resources required to contend with the problem.

The same point is emphasized in the energy study published last year by the International Institute for Applied System Analysis, or IIASA. The study involved some 150 top scientists at one time or another and represents one of the most comprehensive assessments of the outlook for the next 50 critical years of what may well be in absolute terms the world's period of greatest population growth.

The IIASA study concludes that to make a successful transition from fossil fuels to an energy system based on renewable resources, the world economy must expand its productive powers. It must expand in all dimensions, but, most importantly, in the new knowledge and human skill that enlarge the technological base. For such knowledge and skill more than brute capital, is what enables societies in this age to use the same or even fewer resources to produce more.

The IIASA strategy for inventing that future resembles the one I have suggested: a strategy first, of gradual transition from clean, high quality resources--natural gas and oil--to dirtier unconventional fossil resources. The study also takes note of the CO_2 issue, recommending that society incorporate sufficient non-fossil options in the energy supply system so as to allow expansion of that base, if necessary, as the effects of carbon dioxide become better quantifiable through further research.

That means pursuing research leads in technologies that may not seem attractive by the fashionable standards of financial analysis. In a recent landmark article, Professors Hayes and Abernathy of the Harvard Business School warn strongly against such financially biased practices in American Industry; trying to outguess the economics of untried and untested technological approaches can be the death of an industry, and I might add, of a society, too. Some of the tools of this trade--for example, discounted cash flow analysis--are completely unrealistic. Sometimes they are called the Astrophysics of a non-existent universe.

As I have already suggested, Exxon's own R&D philosophy dictates searching for a diversified mix of short- and long-range technological options. I have already alluded to our efforts to boost the energy efficiency of our refineries--a highly immediate and apparent need to management. This need is apparent even though our R&D in some areas may not pay out for years--for example, in advanced separation systems that do not employ normal heat distillation techniques. Another of our major thrusts is in developing more versatile technologies for converting crude residuums to light transportation fuels. The need stems from an evident shift of demand in that direction and from the reduced quality of the average crude oil today. Exxon has begun deployment of an innovation in this area called FLEXICOKING, a processing "garbage can" that can convert virtually any heavy crude or residuum into transportation fuels and fuel gas.

As industry moves down to lower quality resources, there is synergism between such "resid" conversion technologies and our efforts to develop improved synthetics technologies. With the exception of established synthetics operations in South Africa and Canada, falling crude prices and escalating project costs have nipped the synthetic fuels industry in the bud. Many synthetics technologies have turned out to be far more expensive than anyone thought. So price feedback has told us that we must use R&D to bring capital and operating costs down through developing synthetics technologies adaptable to local conditions, resources, and markets. In the process, as I suggested earlier, we will certainly succeed in increasing their efficiency and so reducing CO_2 emissions. In the crucial conversion step, many of today's synthetics technologies operate at efficiences in the range of 60 percent. By the year 2000 we see possibilities for stepping up those efficiencies to nearly 80 percent. And this is not a fundamental limit.

Exxon is working on a very wide variety of synthetics options, including advanced shale retorting and direct coal liquefaction; a catalytic process for producing methane directly from coal; the generation of CO and Hydrogen, or synthesis gas, from coal, lignite, or remotely located natural gas; and the conversion of synthesis gas to fuels and chemicals. On the non-fossil fuel side, Exxon has for many years been doing R&D aimed at improving the fabrication of nuclear fuel elements; and we have been one of several companies in the race to produce cheaper solar voltaic cells made from amorphous silicon.

These efforts suggest primarily the early stages of the transition. For the later stages, some interesting options are beginning to present themselves. A prime difficulty with synthetics resources is their high carbon content. Chemically, that means low ratio of hydrogen to carbon. While the ratio is about four to one in natural gas and 1.8 in crude oil, it is only about 1.5 in oil sands bitumen or raw shale oil, and less than one in coal. In simple terms, a result is that producing these fuels means generating larger amounts of CO_2 than to produce comparable fuels from petroleum. Synfuels require more processing to manufacture and hence more processing heat generated by burning part of the resource.

Prompted by concerns about CO_2 emissions, among other things, some people have suggested a hydrogen economy, a fuel cycle based on hydrogen generated from water not using heat generated by fossil fuels. Perhaps there are ways to generate cheap hydrogen which could then feed directly into a synthetics process. One possible method would be to use thermochemical processes to split water, with advanced solar collectors or nuclear reactors supplying the process heat. The IIASA study notes that in manufacturing coal synthetics such a scheme would cut CO_2 emissions by one-fourth to one-third, compared to the usual coal conversion technologies envisioned. If they could generate hydrogen cheaply, such technologies would also cut overall costs sharply. For example, in the Exxon donor solvent coal liquefaction process, hydrogen accounts for well over a third of the total cost of producing coal liquids.

Summary and Conclusion

To sum up, the world's best hope for inventing an acceptable energy transition is one that favors multiple technical approaches subject to correction--feedback from markets, societies, and politics, and scientific feedback about external costs to health and the environment. This approach is not easy, or comforting to the uninitiated, because there is no overall neat and understandable plan. But prophecies leading to masterminded solutions that commit a society unalterably to a single course are likely to be dangerous and futile. A good sign is that, without any central plan, the world economy has already adopted conservation technologies that are reducing the rate of CO_2 buildup.

In shaping strategies for energy research and development, we must recognize that, generally, societies will give primacy to economic growth, to least-cost energy alternatives, and, in most transportation uses, to liquid fuels. Fortunately, these conditions give science and engineering a lot of room to maneuver. It appears we still have time to generate the wealth and knowledge we will need to invent the transition to a stable energy system.

I hope I do not appear too sanguine about the collective wisdom of our species. History bears ample testimony to the human capacity for grievous folly, as well as achievement and excellence. Clearly, there is vast opportunity for conflict. For example, it is more than a little disconcerting the the few maps showing the likely effects of global warming seem to reveal the two superpowers losing much of the rainfall, with the rest of the world seemingly benefitting. An acceptable future may require a degree of international cooperation that has eluded our grasp to date. An exception is of course science itself and in particular climatology, which even by the standards of science has been distinguished by a remarkable degree of interdisciplinary and international cooperation. As the world continues to grapple with the profound issues posed by the CO_2 buildup, it could seek few better models of international cooperation than what have already achieved.